Appendix D.
Treasure Valley Meteorology & Impact on Carbon Monoxide

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In general, comparing seasonal or annual weather trends and levels of carbon monoxide (CO) is not a productive exercise because there is a very low correlation between long term weather trends and CO levels. Shorter term, daily variations in weather do play a role in the accumulation of CO on specific days. However, predicting day to day variations in weather still proves to be a challenge. This analysis documents the lack of correspondence between CO levels and seasonal weather patterns, and describes the short-term conditions that do contribute to CO buildup.

1. CO Trends

Average CO concentrations have decreased over time in Ada County. The decrease is attributed to reduced CO emissions since the 1970's as a result of cleaner new vehicle emissions standards, the local vehicle emissions testing program, and efforts to improve traffic flow.

The highest eight-hour value measured each year declined from 20 parts per million (ppm) in the late 1970's to about 8 ppm in recent years. An average of the maximum daily eight-hour concentrations recorded over the winter season declined from 10 ppm in the late 1970's to below 5 ppm in recent years. The number of days with maximum eight-hour values greater than 8 ppm fell from 92 days in 1977 to 1 day or fewer in recent years.

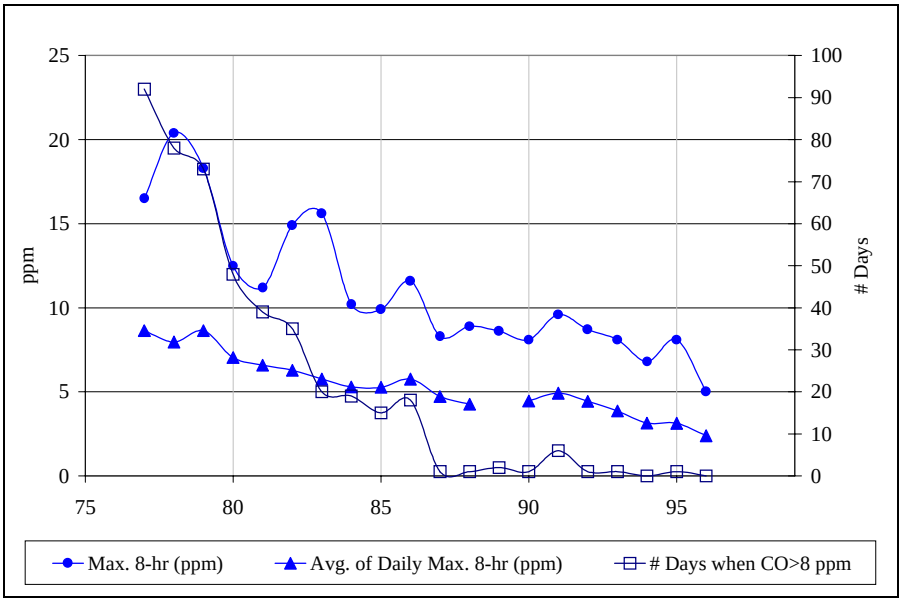

Figure 1. Changes in Carbon Monoxide Levels; 1976-1996

Based on trends shown in monitoring data from the last 20 years, the highest eight-hour value that would be expected in 1995 would be 6.7 ppm, and the average of maximum daily eight-hour values

for the winter months in 1995 would be 3.1 ppm. Based on 1984 through 1998 data the maximum variation, or the most that actual measured concentrations departed from the expected value, is about 2 ppm.

The potential maximum CO levels are determined by adding the maximum variation to the expected values. With 1995 CO emissions levels, the maximum potential eight-hour CO level is estimated to be 8.7 ppm. Predicted CO values for the years 1996 through 1998 also agreed with the actual observed levels.

If the trend in CO concentrations continues, it is estimated that the potential maximum eight-hour CO concentration would be about 7 ppm between the years 2000 and 2005.

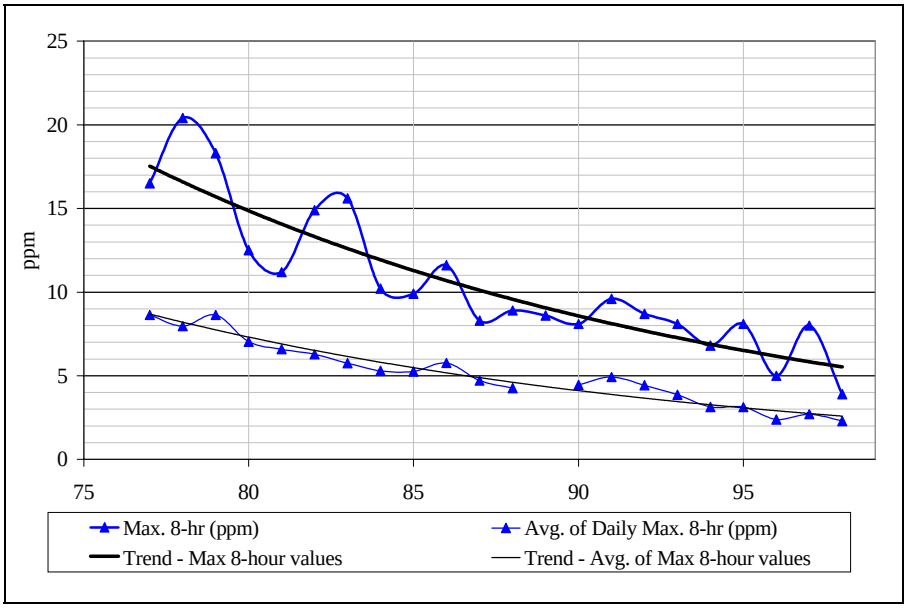

Figure 2. Eight-Hour Maximum & Average Of Eight-Hour Maximums; 1977-1997

2. Stagnation Conditions

Meteorological Conditions

The Treasure Valley is a region of complex terrain bordered by a mountain range to the north and east and a sequence of terrain benches to the south. These topographical features contribute to a tendency for stagnant weather conditions, which allow pollution to build up.

A study by Wolyn and McKee (1989) defined a meteorological condition termed a Deep Stable Layer (DSL). DSL is an atmospheric structure in which at least 65% of the lowest 1500m has strong inversion layers (lapse rate of -2.5 °C per km or less). High-pressure weather systems, common during the winter season, create very stable conditions that are associated with the development of DSL conditions. These conditions prevent air circulation, and cause pollution levels to build up. The Wolyn and McKee study showed that in December and January about 15% of all days in Boise had DSL conditions.

Mixing height is a term to describe the elevation level up to which vertical mixing of air takes place. A low mixing height indicates weak dispersion and the potential for pollutant concentrations to increase. Based on data provided by National Weather Service, it was found that the mixing height in Boise is often lower at 5:00 p.m. than at 5:00 a.m.

In addition to mixing height and DSL, a condition termed a Lower Stable Layer (LSL) has been identified as playing a role in CO accumulation. LSL is defined as a condition when 10% or more of the lower 500 meters of the atmosphere consists of strong inversion layers (lapse rate greater than -2.5 °C per km).

Trends

Historical data shows that the number of DSL days has decreased since the mid-1980's, while the number of LSL days throughout the year has increased, and the number of winter LSL days has held fairly steady.

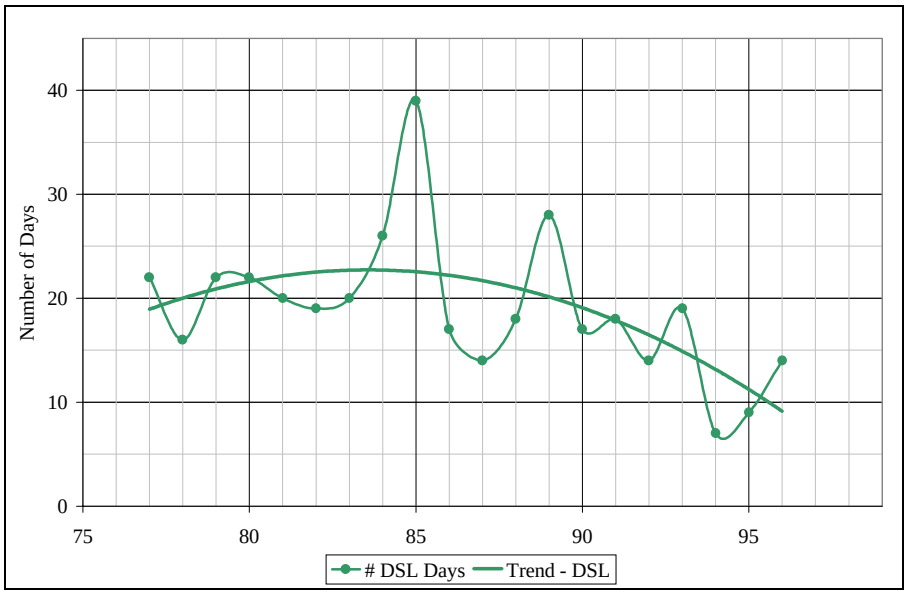

Figure 3. Number of DSL Days; 1977-1996

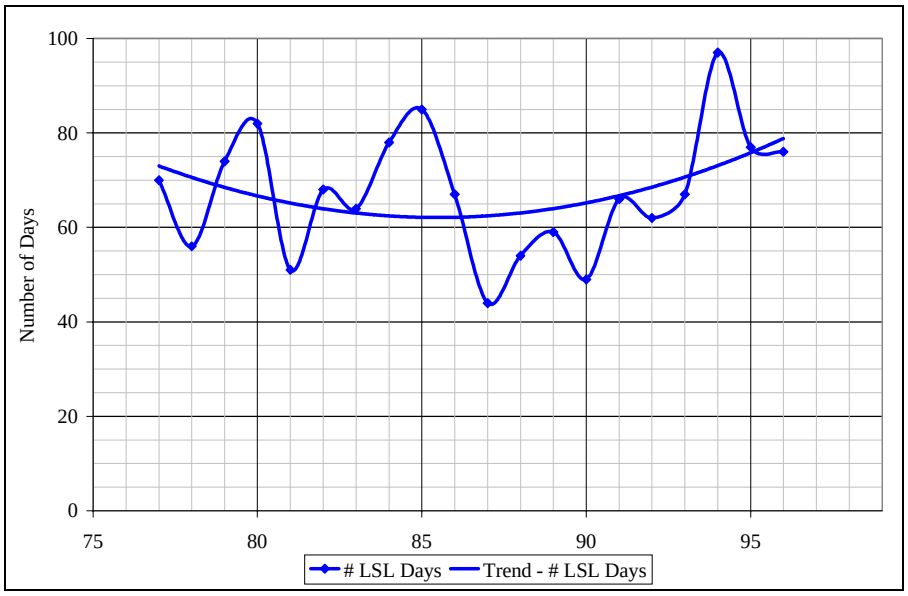

Figure 4. Number of LSL Days; 1977-1996

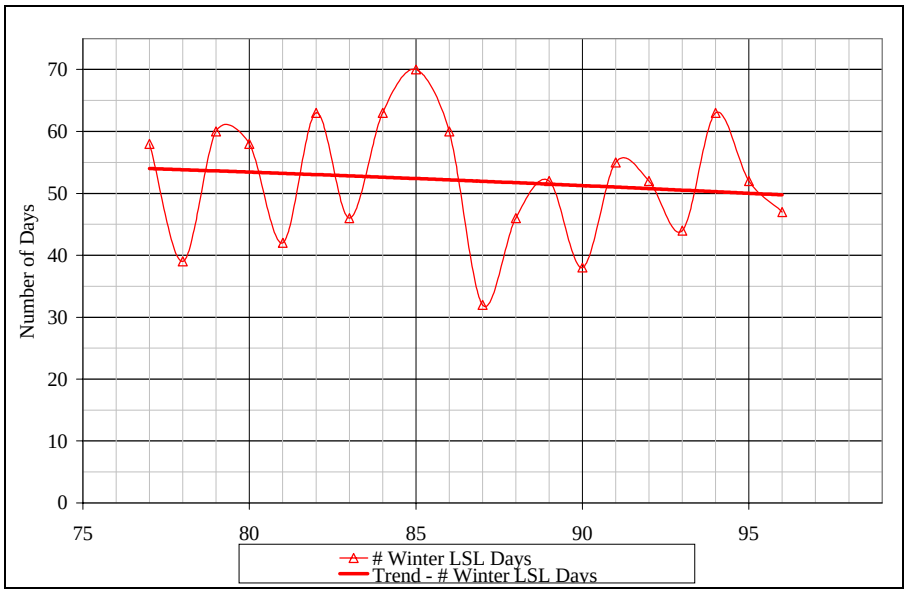

Figure 5. Number of Winter LSL Days; 1977-1996

3. Correlation: Number of Days with Elevated CO and Number of Days with Stagnation Conditions

A comparison of measured CO concentrations, number of days with higher CO concentrations, and number of days with stagnation conditions (DSL or LSL) shows no obvious correlation between stagnation conditions and CO levels.

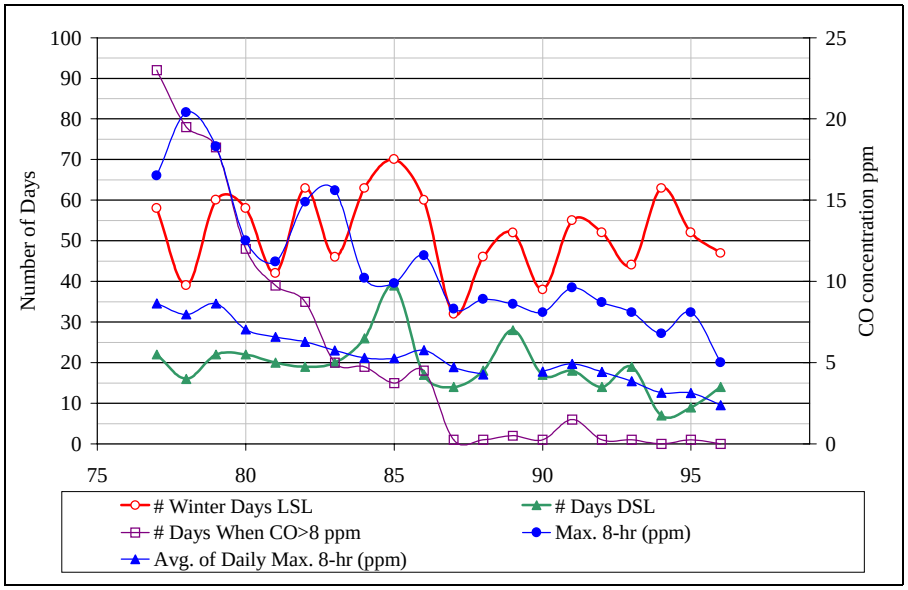

Figure 6. Trends In CO Concentrations & Stagnation Conditions; 1976-1997

While there appears to be no connection between high CO concentrations and the frequency of stagnation conditions, a comparison of conditions that depart from expected values can provide additional information. For example, it would be expected, based on the trends, that in 1988 there would be 52 winter days with LSL conditions. However, there were actually 46, which departs from the expected by 6 days. (See Figure 5.)

This analysis shows that low mixing height and the presence of LSL correlate most closely to high CO levels, while the presence of DSL conditions does not appear to have significant impact on CO concentrations. The difference between the expected and the actual number of winter days with LSL conditions, in comparison to the difference between the expected and the actual number of days with high CO concentrations (8 ppm or greater), shows a positive correlation coefficient of +0.47.

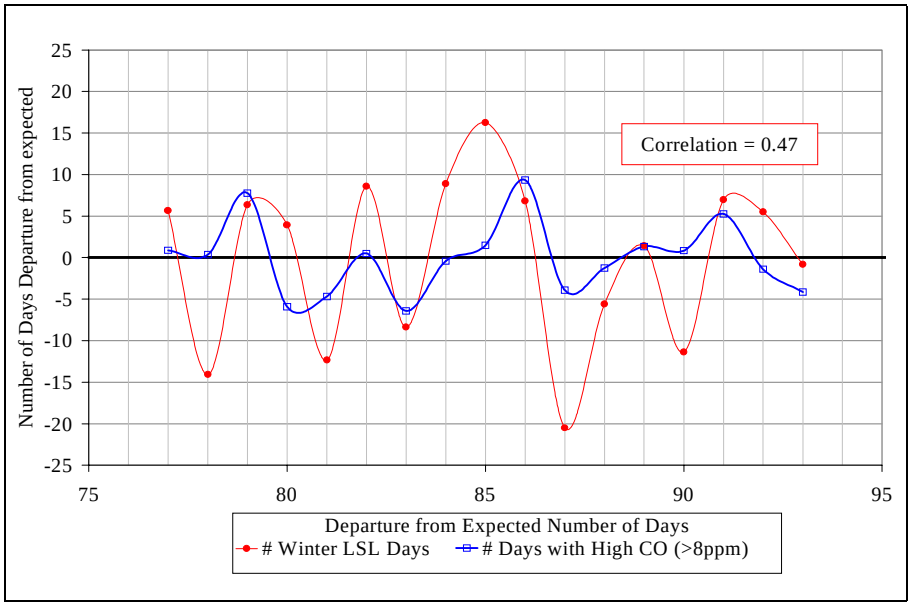

Figure 7. Difference Between Expected & Actual Number Of Days; Winter LSL Days, High CO Days (CO > 8 ppm)

DSL conditions, while having a critical role in accumulation of PM_{10} pollution, has less impact on CO accumulation. The same comparison on DSL conditions results in a correlation of only +0.11.

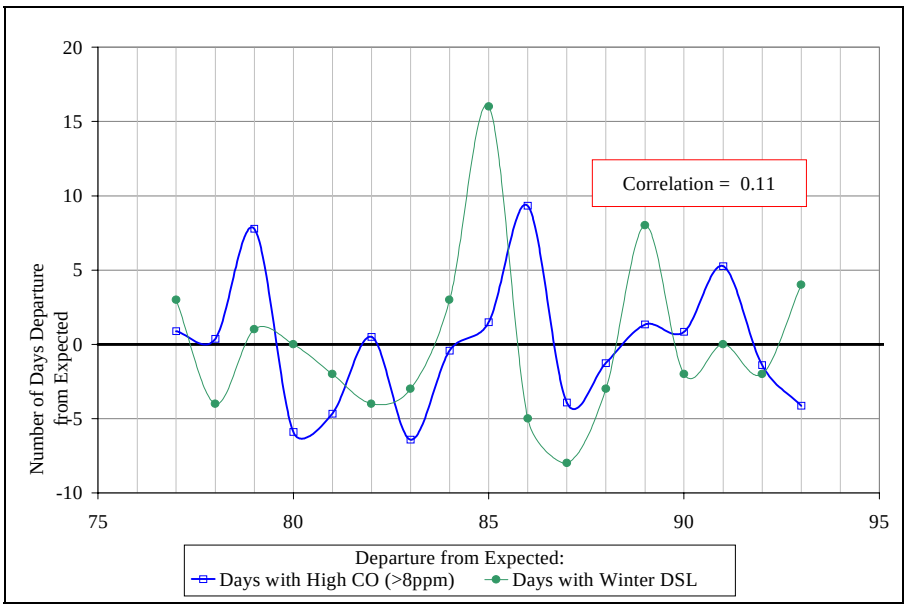

Figure 8. Difference Between Expected & Actual Number Of Days; Winter DSL Days, High CO Days (CO > 8 ppm)

4. Comparison of Meteorological Factors & 12 Selected Days With High Carbon Monoxide Concentrations

While long term weather trends are less predictive of potential high CO levels, day to day weather variations do effect the accumulation of CO. An analysis was conducted comparing the meteorological conditions on the days with elevated CO concentrations (eight-hour concentrations of 8.0 ppm or greater).

The ten days with the highest CO concentrations between 1993 and 1996 were chosen. In order to extend the time period of the analysis to cover the time period over which the design value for CO was determined for Ada County (1995-1996), two additional days in 1996 were also added since no days in 1996 were a part of this group. Neither of the 1996 days had particularly high CO concentrations (5.0 ppm), nor did the meteorological conditions match those typically associated with elevated CO levels.

Of the 12 days included in the analysis, all but one peak concentration was recorded during later afternoon or evening hours. The day in which the peak concentration occurred in the early morning hours (11/10/96) was one of the 1996-days, included to expand the time period of the study, and was not a particularly high CO concentration. The temperatures in most cases were lower than normal, particularly the minimum temperature. Winds were generally light. The mixing heights at 4:00 p.m. were close to, or lower than, 400 meters in all cases. Nine of the twelve days had 4:00 p.m. mixing heights that were significantly lower than 400 meters. Of the days analyzed, only one was not an LSL day (January 18, 1993), and one could not be determined due to inadequate data (January 10, 1994).

Table 1. Meteorological Conditions On 12 Days; 10 Days With Highest CO Levels In 1993 To 1995 and Two Highest Days From 1996

Date	CO	Max Temp.	Min Temp.	8 hr. Avg. Temp.	Time of peak conc.	LSL	Mixing Height 4:00 a.m.	Mixing Height 4:00 p.m.	Surface Wind Speed 4:00 p.m.
	(ppm)	(F)	(F)	(F)	(Hour)		(m)	(m)	(m/s)
Normal	--	**38**	**27**	**32.7**	--	--	--	--	--
11/17/95	8.1	**59**	**36**	**51.0**	8:00 p.m.	Yes	323	112	2
01/13/93	8.1	31	6	24.5	6:00 p.m.	Yes	676	260	5
01/12/93	7.3	24	2	16.0	6:00 p.m.	Yes	200	129	4
01/14/93	7.2	**39**	17	**33.8**	10:00 p.m.	Yes	314	13	3
01/10/94	6.8	**40**	**30**	**33.5**	6:00 p.m.	n/d	129	104	3
01/15/93	6.7	30	22	24.8	6:00 p.m.	Yes	183	360	3
11/29/93	6.7	**44**	24	**33.5**	7:00 p.m.	Yes	347	266	2
01/06/95	6.4	35	21	30.0	10:00 p.m.	Yes	481	134	2
01/08/93	6.4	25	19	22.8	6:00 p.m.	Yes	n/d	222	**9**
01/18/93	6.4	31	16	25.8	7:00 p.m.	**NO**	301	406	3
11/10/96	5.0	**56**	**33**	**38.0**	**3:00 a.m.**	Yes	266	325	2
11/12/96	5.0	**52**	**32**	**35.0**	11:00 p.m.	Yes	251	66	4

Bold Type indicates conditions outside of norm, or outside of typical stagnation or DSL parameters.

5. Temperature

Based on the average of the historical values, calendar year 1993 had a higher than normal number of heating-degree-days in the winter months, meaning it was colder than normal. Calendar year 1994 would be considered to have a normal number of heating-degree-days. 1995 and 1996 were warmer than normal, with fewer heating-degree-days. There is no corresponding fluctuation in the number of days with higher CO concentrations for these years.

Table 2. Heating-Degree-Days by Month (winter)

Year	Nov	Dec	Jan	Feb	Total
1993	960	975	1,239	1,004	4,178
1994	967	1,066	993	839	3,865
1995	610	984	887	652	3,133
1996	1,000	859	703	883	3,445
Normal	**753**	**1,082**	**1,116**	**815**	**3,766**

However, CO emissions may increase due to reduced efficiency in fossil fuel burning and emissions control equipment under colder conditions. Therefore, even in a year when the winter is warmer than normal overall, the occurrence of several days with colder-than-normal temperatures could result in higher CO concentrations on those days.

6. CO Trends

Daily CO Concentration Trends

Similar to many other areas, hourly CO concentrations in Boise exhibit a bi-modal, diurnal trend. In general, there are two peaks in the one-hour average concentrations each day, both associated with increased traffic periods (morning and afternoon rush hours). The largest peak generally occurs in the late afternoon hours, consistent with surveys of vehicle-miles-traveled that indicate traffic levels are highest at this time.

The maximum eight-hour concentration usually coincides with afternoon rush hours. The concentration drops considerably after midnight, attributed to reduced driving activity. This pattern of CO levels has remained similar since the mid-1970's, although concentration levels have been significantly reduced.

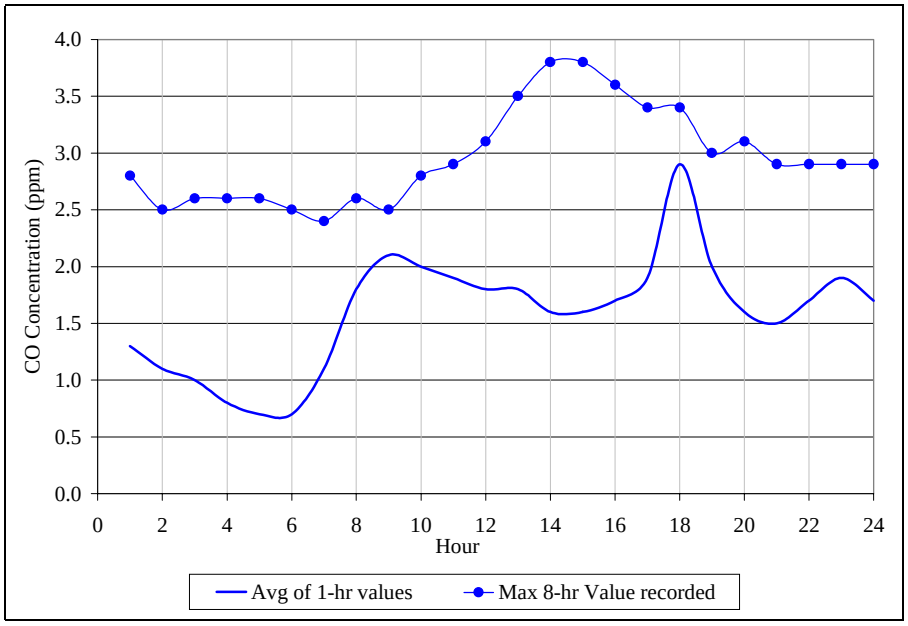

Figure 9. Diurnal Trends Of CO Concentrations; January 1998

*Note: The one-hour average represents the **mean value** of all measurements taken for each hour during the month. The maximum eight-hour concentration represents the **highest** eight-hour value recorded at each hour during the month.*

Weekly CO Concentration Trends

Based on historical data, the probability of a high CO concentration is greatest on Friday, and lowest on Sunday, closely mirroring driving activity levels. Overall concentrations have declined in recent years, with very few days registering higher than 8 ppm since 1992.

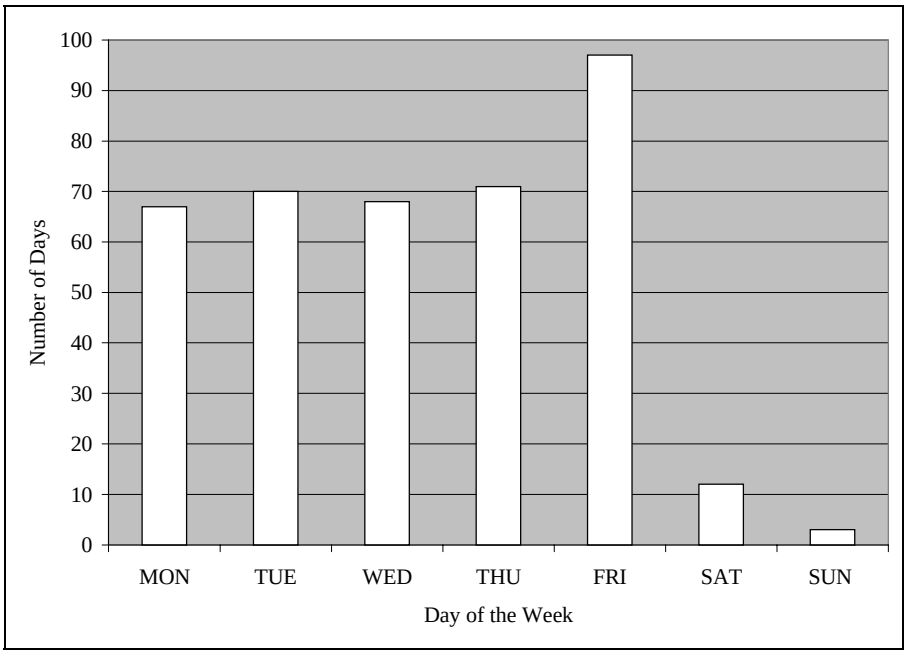

Figure 10. Number Of High CO Days (> 8 ppm) Versus Days Of The Week; 1977-1992.

Summary

The overall CO levels in Ada County have decreased significantly since the mid-1970's. This trend is expected to continue in the near future. The dominating factor controlling CO levels appears to be emissions from motor vehicles. Low level, short term stable meteorological conditions termed LSL conditions play a role in CO accumulation when it occurs in conjunction with high emissions periods. These meteorological conditions usually occur on late afternoons in winter, and happen to coincide with rush hour traffic patterns.

Assuming that CO emissions continue on the current trend and remain below the 1995 level, an estimated eight-hour maximum of 8.7 ppm could occur under these LSL conditions. In the future, this estimated maximum eight-hour value drops to about 7 ppm. Although the possibility of exceedances cannot be excluded due to the complicated nature of emission and weather variations, the probability of exceedances is low, assuming the CO emissions rate remains at or below the 1995 level.

Evidence shows that elevated CO concentrations are more related to low level temperature inversions that coincide with peak emissions periods. The occurrence of such low level temperature inversions were within the norm during 1995 and1996. Therefore these years are considered to have representative meteorology for the purposes of analyzing CO.